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Noise Attenuation of the HGU-56/P Aircrew Integrated Helmet System When Worn with the Combat Vehicle Crewman Hood (BALACLAVA)

By Martin B. Robinette, William A. Ahroon, and Dale A. Ostler

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Aircrew Protection Division

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The HGU-56/P Aircrew Integrated Helmet System (AIHS) is designed to provide impact protection and noise attenuation to U.S. Army rotary-wing aircraft crewmembers. The ability of any helmet to attenuate environmental noise depends on an adequate seal between the earcup and the user's head. Any object (e.g., eyeglass frames) or practice (e.g., loose chin strap) that interferes with the seal between the earcup and the head will compromise both helmet retention (with resultant effects on impact protection) and noise attenuation. The noise attenuation of the HGU-56/P AIHS was measured with and without the flight approved balaclava (combat vehicle crewmember hood). The balaclava interferes with the earcup seal and adversely affects the noise attenuation of the HGU-56/P AIHS. When worn without the additional hearing protection provided by earplugs or the Communications Earplug, the balaclava can significantly affect operational capabilities. Results obtained from using minimal fitting instructions did not differ from those obtained using the ANSI S12.6-1997 Experimenter-supervised fit method. Care must be taken to fit the flight helmet correctly in order to ensure adequate noise and impact protection.

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Introduction

The HGU-56/P Aircrew Integrated Helmet System (AIHS) (Figure 1) is designed to provide impact protection and noise attenuation to U.S. Army rotary-wing aircraft crewmembers. It has replaced the 1980's vintage SPH-4B flight helmet and is used by most U.S. Army rotary-wing aircrew flying aircraft other than the AH-64 Apache (which uses a different helmet system). The ability of any helmet to attenuate environmental noise depends on an adequate seal between the earcup and the user's head. Any object or practice that interferes with the seal between the earcup and the head will compromise noise attenuation. The manipulation of the earcup seal may also affect helmet retention (with resultant effects on impact protection) and, while not addressed in this report, we feel that the possible effects on helmet retention should be investigated.

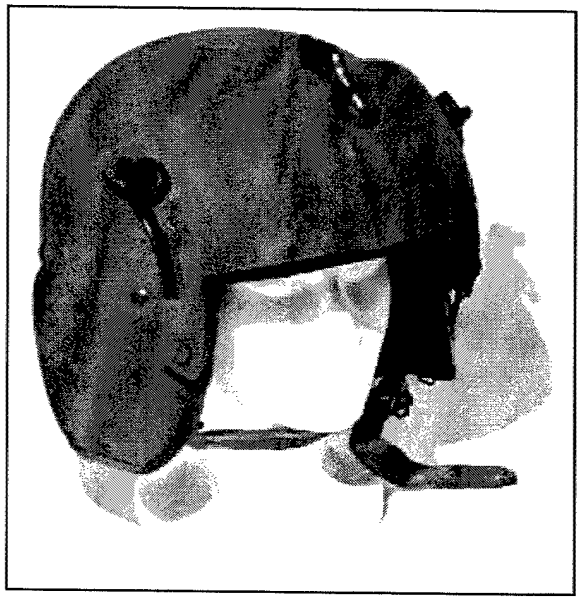

Figure 1. Gentex HGU-56/P AIHS.

Several investigations report that the use of eyeglasses can negatively affect the noise attenuation of an aviator's helmet (Mozo et al., 1974; Nixon and Knoblach, 1974; Mozo and Murphy, 1997; Ahroon et al., 2002). Similar to eyeglasses and other ancillary devices, the balaclava, a cold weather hood, can also have an effect on noise attenuation. This paper describes the noise attenuation of the HGU-56/P AIHS when used with the flight-approved balaclava (Figure 2).

Methods

Testing was performed in accordance with the American National Standard Methods for Measuring the Real-ear Attenuation of Hearing Protectors (ANSI S12.6-1997). An informed-user fit procedure (not included in the standard) was employed and is detailed below.

Figure 2. Hood, combat vehicle crewman (balaclava).

Subjects

Normal-hearing Army aviation students who had successfully completed the Basic Combat Skills (BCS) course were recruited. Student at this stage of training have been instructed on proper helmet fit and have been given sufficient time (32 weeks) to obtain a comfortable and appropriate helmet fit. The purpose of the study was explained to each subject. Each subject read and signed an informed consent form (Appendix A) and then completed a questionnaire regarding his/her hearing health (Appendix B). Ear and head sizes were measured, an otoscopic inspection was performed, and an audiogram was collected on each subject. At any time during this preliminary process, if a subject failed to qualify for ANSI S12.6 Method A testing, he/she was released. Subjects were permitted to withdraw from the study at any time.

Sixteen (16) volunteer subjects were used. All subjects were male. Four subjects failed to meet the 25 dB hearing level criterion as specified by ANSI S12.6-1997 and one subject withdrew from participation. Thus, 11 subjects participated in data collection. Each subject used his or her own helmet for all test conditions. During data collection for one subject, it was clear that the flight helmet had not been fitted correctly. The data from that subject were not included in the mean attenuations reported or in the data set to which statistical procedures were applied. The data from that single subject are noted below.

Equipment

The real-ear test procedure utilized Tucker-Davis Technologies (TDT) System II psychoacoustic test modules controlled by a general-purpose personal computer using custom-written software to control the real-ear procedure. Figure 3 presents a schematic of the experimental setup. Test stimuli were created by filtering the output of a WG2 Waveform Generator by a PF1 Programmable Filter and attenuating this signal by two PA2 Programmable Attenuators connected in series. The output of the WG2 was gated on and off using a TG6

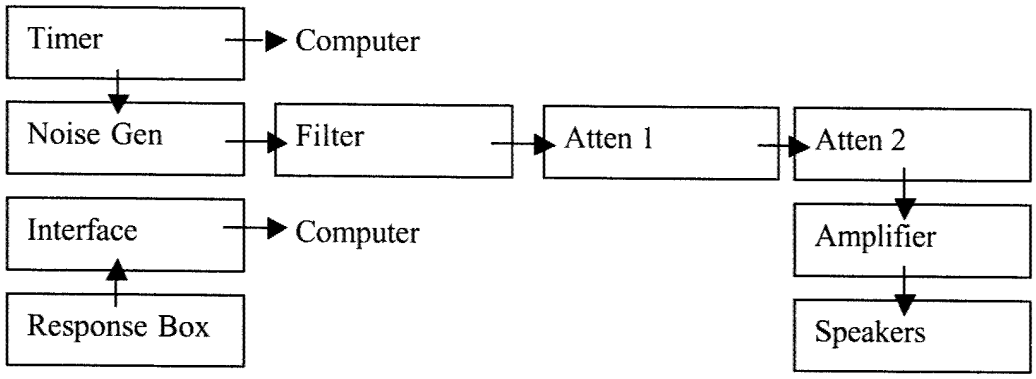

Figure 3. Schematic representation of the equipment used for real-ear attenuation at threshold measurements.

Timing Generator with 400 ms cycle time (two-and-one-half times a second, 50 percent duty cycle). The output of the attenuators placed in series was connected to a McIntosh Model MC 2255 Stereo Power Amplifier and routed to a speaker system consisting of three Altec Model 612C speakers. The sound field created by the system described satisfied the stimulus conditions mandated by ANSI S12.6-1997.

Procedure

After preliminary screening and audiometric and anthropometric measurements, subjects were trained on the testing procedure. A TDT response box (RBOX) was used by the subject to adjust the level of the signal (via the programmable attenuators). Subjects were given the instruction to "adjust the loudness of the signal until it is 'just barely audible'." Subjects satisfied the training and reliability requirements IAW ANSI S12.6-1997 with at least three consecutive unoccluded third-octave audiograms with a range no greater than six decibels (dB). Threshold during training and data collection was determined as the average of four consecutive judgments at a single test signal, with the condition that the range of these four judgments be no greater than five decibels. If response variability was large and this criterion was not reached after 20 judgments, the testing was paused and the subject was instructed on the use of the response box and reminded of the listening strategy. Subjects seldom required more than 20 trials to reach criterion with the vast majority of thresholds collected with less than 6 responses.

Three test conditions were performed: the HGU-56/P AIHS alone using informed-user fitting instructions, and the HGU-56/P AIHS worn with balaclava (combat vehicle crewmen hood; NSN 8415-01-111-1159) using informed-user fitting instructions. For the informed-user fit, the subjects were told, "Please put on your flight helmet the same way you normally do for flight operations." Subjects were not allowed to wear glasses or other forms of hearing protection (earplugs) during testing. The order of the first two tests was counterbalanced. Finally, a second evaluation of the HGU-56/P AIHS alone was conducted, this time following the ANSI S12.6-1997 Experimenter-supervised fit procedure (Method A), with experimenter instructions and fitting noise.

In each evaluation, two occluded and two unoccluded thresholds of third-octave bands of noise centered at octave frequencies from 125 Hz to 8000 Hz were obtained for each condition. A "trial" consisted of one occluded and one unoccluded measurement. The real-ear attenuation at threshold at each test center frequency was calculated as the average of the difference between the occluded and unoccluded thresholds for the two trials. A head-positioning device consisting of a string suspended from the test booth ceiling down to a level approximately equal to the elevation of a subject's nose was used to maintain the subject's head at the stimulus reference point, the point where stimulus calibration was performed. During training and testing, subjects were observed over a closed-circuit television and notes made regarding correct use of the hearing protective devices (HPDs).

Statistical analyses were performed using STATISTICA® Release 5 from StatSoft®, Inc. The probability of a Type I error was set at 0.05 for all analyses.

Results

The real-ear attenuation for HGU-56/P alone and with balaclava is illustrated in the left panel of Figure 4 and depicted in tabular form in Table 1. A two-way analysis of variance with repeated measures on all factors was performed on the mean attenuation. There was a statistically significant main effect of third-octave band center (test) frequency ($F = 174.43$, $df = 6/54$, $p < .05$), which was expected, based on our knowledge of the frequency-specific nature of hearing protection devices. There was a statistically significant main effect of device ($F = 5.63$, $df = 1/9$, $p < .05$) and a significant interaction of device and frequency ($F = 2.87$, $df = 6/54$, $p < .05$) indicating that there was a difference between the mean attenuation that was dependent on test frequency. Duncan's multiple-range[1] post-hoc analyses revealed that the statistically significant interactions were the result of significantly less attenuation of the helmet when worn with the balaclava at the 125, 500 and 2000 Hz test frequencies.

Also depicted in Figure 4 (right panel) and Table 1 are the mean real-ear attenuation at threshold values for the HGU-56/P AIHS alone, tested using the two different helmet fitting

[1] The Duncan's multiple-range test was used for post-hoc comparisons because only a limited set of comparisons, those between mean insertion loss at the same frequencies, were of interest in these analyses (see Keppel, 1973).

procedures: the informed-user fit in which the experienced aviator was simply told to don his helmet the same way as during flight operations, and the ANSI S12.6-1997 Experimenter-supervised fit (Method A) as noted above. The test using the informed-user fit procedure was always performed before the Method A procedure test. It is clear that there were little differences between the mean sound attenuation values when tested using the two different fitting methods. A two-way analysis of variance with repeated measures on both factors revealed a statistically significant effect of third-octave band center frequency (F=91.47, df = 6/54, $p < .05$) but no statistically significant effect of fitting method ($F = 0.71$, $df = 1/9$). The interaction of fitting method and frequency also was not statistically significant ($F = 1.27$, df = 6/54).

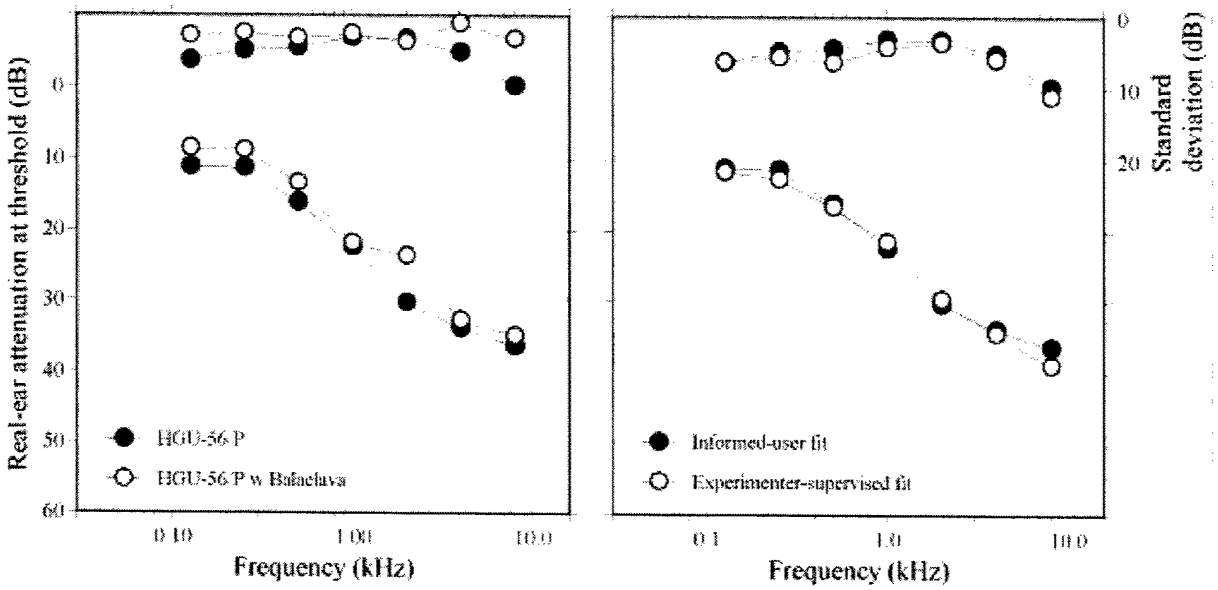

Figure 4. The real-ear attenuation at threshold (in dB) for the HGU-56/P Aircrew Integrated Helmet System (AIHS) (n=10). The left panel shows the hearing protection with and without the balaclava using informed-user fitting instructions. The right panel compares the HGU-56/P attenuation (without balaclava) measured using informed-user and ANSI S12.6-1997 Experimenter-supervised fit instructions.

Effect of helmet fit on noise attenuation

As noted above, the third HDP evaluation performed employed the ANSI S12.6-1997 Method A Experimenter-supervised fit procedure. A fitting noise was presented while the subject donned his helmet, and the subject was told to adjust the helmet fit to minimize the loudness of the noise. Ten subjects fit and adjusted the helmet without difficulty. However, one subject (identified as Subject 11 in the appendices), during this final (Method A) evaluation, required several pads to be inserted between the helmet shell and the earcup on each side to secure a proper fit. These pads are normally supplied with the HGU-56/P AIHS as an "Earcup

Spacer Kit" (NSN 8415-01-395-0004). With the pads inserted, noise attenuation improved appreciably while still maintaining a comfortable fit. Indicative of a poor initial fit, the noise attenuation values at the lowest two test frequencies improved by 19.25 and 14.75 dB respectively, suggesting a significant seal leak during the earlier test. (No other subject demonstrated a large difference in noise attenuation at the low-test frequencies.) The fact that this aviator's helmet was not properly fit is disturbing. A properly fit helmet is necessary not only for adequate noise protection but also for helmet retention in the event of an accident.

Table 1.
The real-ear attenuation at threshold (in dB) for the HGU-56/P Aircrew Integrated Helmet System using the Experimenter-supervised- and informed-user fit procedures (n=10).

	Test frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Informed-user fit procedure – HGU-56/P							
$\overline{X}$	11.11	11.28	16.10	22.38	30.31	33.84	36.35
s	6.30	4.88	4.45	3.10	3.29	5.17	9.79
Informed-user fit procedure – HGU-56/P with Balaclava							
$\overline{X}$	8.51	8.81	13.41	21.94	23.71	32.78	34.94
s	2.92	2.53	3.23	2.65	3.78	1.16	3.31
Experimenter-supervised fit (Method A) procedure							
$\overline{X}$	11.65	12.64	16.58	21.53	29.68	34.44	38.90
s	6.33	5.70	6.37	4.31	3.64	5.99	11.13

Discussion

The use of ancillary devices with the HGU-56/P AIHS is known to degrade the sound attenuation of the flight helmet (Mozo & Murphy, 1997). When using the balaclava with the HGU-56/P AIHS the resulting sound attenuation properties should be considered and additional protection should be worn as needed. If aircrew are using earplugs in addition to the sound-attenuation flight helmet as recommended for some aircraft (see the technical manual [TM 1-

1520-237-10, 1999] for the UH-60A Black Hawk), the use of a balaclava will not impact the total noise protection appreciably (Berger, 1983). Under other circumstances, however, when earplugs are not required and/or used, the decision to use a balaclava will have an effect on operational capabilities. With this in mind, we computed the maximum exposure duration for a crewmember or passenger in the cabin of a CH-47D given different flight profiles (see Appendix G). IAW DODI 6055.12 (DOD, 1991) and data from this study, the maximum safe duration is severely limited when wearing the balaclava. Some of the exposure limitations (from 1.6 to 4.3 hours) were mission limiting (see Table 2). The use of a balaclava can reduce the noise protection of the HGU-56/P AIHS in certain, perhaps not very unusual, circumstances. That is, in aircraft or conditions where double hearing protection is not mandated, the use of a balaclava can put the hearing of aircrew and passengers at risk for noise-induced hearing loss. Aircrew should be cognizant of the limitations of the helmet to protect hearing when ancillary devices are worn and make responsible decisions regarding additional hearing protection (i.e., double-protection). Aircrew should also have at their disposal the means to determine safe exposure duration given their expected flight profile.

The differences between experimenter-supervised fit and informed-user fit were minimal and showed no statistically significant differences. Only one subject made significant changes in the experimenter-supervised fit, which resulted in increased attenuation. This would suggest that while most aviators correctly adjust and wear the helmet, appropriate training and supervised fitting is still needed to achieve expected attenuation benefits. This study does not suggest that similar results would be seen with earplugs. The greater variability encountered in the fitting of earplugs may result in greater variability in attenuation.

Table 2.
The maximum allowable exposure times for crewmembers in a CH-47D under different flight profiles with and without use of balaclava, based on DODI 6055.12. Maximum allowable exposure times were calculated using the informed-user fit data.

CH-47D		Allowable time (hr/day)	
Position	Condition	HGU-56/P	w/ Balaclava
Aft Cabin[2]	90 knot	2.6	1.6
	Hover	5.9	3.3
Center Cabin	90 knot	7.6	4.3
	Hover	6.7	4.0

[2] Cabin refers to the cargo/passenger seating area.

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Appendices

Appendix A. Volunteer Agreement Affidavit.

Appendix B. Volunteer Screening Questionnaire.

Appendix C. Analysis of variance summary table for the HGU-56/P versus HGU-56/P with balaclava comparison.

Appendix D. Probabilities for Duncan multiple range post-hoc tests for the HGU-56/P versus HGU-56/P with balaclava comparison. Only the comparisons between means at the same center frequency test band are highlighted. The statistically significant comparisons are underlined.

Appendix E. Analysis of variance summary table for the Informed-user versus Experimenter-supervised fit comparison.

Appendix F. Probabilities for Duncan multiple range post-hoc tests for the Informed-user versus Experimenter-supervised fit comparison. Only the comparisons between means at the same center frequency test band are highlighted. The statistically significant comparisons are underlined.

Appendix G. Maximum allowable exposure times for crewmembers in a CH-47D under different flight profiles with and without use of balaclava, based on DODI 6055.12.

Appendix H. Mean and standard deviations of the insertion loss of the HGU-56/P AIHS using the informed-user fit procedure.

Appendix I. Mean and standard deviations of the insertion loss of the HGU-56/P AIHS worn with balaclava using the informed-user fit procedure.

Appendix J. Mean and standard deviations of the insertion loss of the HGU-56/P AIHS using the Experimenter-supervised fit procedure.

Appendix K. Occluded and unoccluded thresholds for each trial of the HGU-56/P AIHS using the informed-user fit procedure.

Appendix L. Occluded and unoccluded thresholds for each trial of the HGU-56/P AIHS worn with balaclava using the informed-user fit procedure.

Appendix M. Occluded and unoccluded thresholds for each trial of the HGU-56/P AIHS using the Experimenter-supervised fit procedure.

Appendix A.

Volunteer Agreement Affidavit.

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 70-25 or AR 40-38; the proponent agency is OTSG.

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087

Principal Purpose: To document voluntary participation in the Clinical Investigation and Research program. SSN and home address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study; implementation of medical programs; adjudication of claims; and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A – VOLUNTEER AFFIDAVIT

Volunteer Subjects in Approved Department of Army Research Studies

Volunteers under the provisions of AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or diseases which is the proximate result of their participation in such studies.

I, _____ SSN_____,

having full capacity to consent and having attained my _____ birthday, do hereby

volunteer to participate in *the research protocol, "Real-ear Attenuation at Threshold of the HGU-56/P Aircrew Integrated Helmet System when used with Balaclava"*

under the direction of *William A. Ahroon, Ph.D.*

conducted by *the United States Army Aeromedical Research Laboratory, Fort Rucker, AL 36362-0577*

The implications of my voluntary participation: duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

Dr. Ahroon, CPT Robinette, MAJ Ostler, or Ms. Gordon

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or study-related injury, I may contact

Dr. Patricia A. LeDuc

at *Human Subject Review Committee, U.S. Army Aeromedical Research Laboratory, Building 6901, P.O. Box 620577, Fort Rucker, Alabama 36362-0577 (334) 255-6872*

I understand that I may at any time during the course of the study revoke my consent and withdraw from the study without further penalty or loss of benefits; however I may be required (military volunteer) or requested (civilian volunteer) to undergo certain examinations if, in the opinion of the attending physician, such examinations are necessary for my health and well-being. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled..

PART B – TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: *(Provide a detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25.)*

You will be participating in a study to assess effect of Cold Weather Gear (Balaclava) on the noise protection provided by the HGU-56/P Aircrew Integrated Helmet System (AIHS). The noise levels used in this test are not hazardous to hearing and you will be at no risk of hearing loss as a result of participation in this study.

First, you will complete a questionnaire, which asks about your general health and hearing. You will be asked to submit a copy of your DA Form 759 Individual Flight Record and Flight Certification--Army to allow accurate description of your rotary-wing noise exposure. Your ears will be inspected and your head will be measured using standard evaluation devices. Next, your hearing will be tested by a certified audiologist or hearing conservationist to ensure that you have normal hearing relative to the American National Standards Institute definitions for the purpose of this test. Following this introduction, you will be trained in the psychophysical procedure to be used in the evaluations of hearing protection.

During the testing, you will be asked to adjust (using buttons on a control box) the loudness of a narrow band of noise (that sometimes may be like a "chirping" sound) so that the sound is just barely audible. When the sound is just barely audible, you will press the "SET" button and another trial will start. The number of trials for each stimulus type will depend on the stability of your responses. Seven different sounds will be used. At least five practice "runs" will be completed before actual data collection on any device will begin. A total of four "audiograms" will be conducted for each device, alternating between devices in place and devices removed.

Half of you will be tested with the HGU-56/P and Balaclava first and the other half will be tested with the helmet only first. For each hearing protection strategy, two measurements with the helmet on and two measurements with the helmet off will be made. Half of you will be tested with the helmet on first then with the helmet off. The other half will be tested with the helmet off first. A final test will be performed of the helmet alone. A complete set of data should be able to be collected in 2-3 hours.

You will receive no personal benefit from participation in this study. Participation in this study is strictly voluntary, and you have the right to withdraw at any time without adverse consequences or loss of benefit.

The data from your participation in the study will be kept as confidential as possible. Representatives of the U.S. Army Medical Research and Materiel Command may inspect the records of this test and evaluation. Group data will be summarized in reports, but your name will never be identified with any specific data. None of the information obtained from this study, which identifies you in any way, will be released to a public forum without your express consent.

I have received a copy of this volunteer consent form and have read and fully understand its contents. I am signing this form voluntarily.

I do do not (*check one and initial*) consent to the inclusion of this form in my outpatient medical treatment record.

SIGNATURE OF VOLUNTEER DATE

PERMANENT ADDRESS OF VOLUNTEER TYPED NAME OF WITNESS

Appendix B.

Volunteer Screening Questionnaire.

Volunteer Screening Questionnaire BALACLAVA

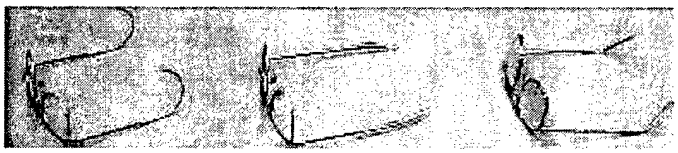
Name _____ SSN: _____

DOB: _____ Rank: _____ Gender: M / F

1. Do you feel that you are currently in good health? NO YES
2. Do you have any medical waivers, profiles or conditions? NO YES
3. Have you ever had any problems with hearing? NO YES
4. Have you ever had any problems with balance, dizziness, motion sickness, ear pain or ear discharge? NO YES
5. Do you have any allergies? NO YES
6. Are you currently suffering from any illnesses? NO YES
7. Have you taken any medication within the past three days? NO YES
8. Do you normally wear eyeglasses with your helmet? NO YES
   a. If YES, what type temple arms or frames are on the glasses:

      Cable [ ] (curved) Bayonet [ ] (straight) Skull [ ] (semi-curved) Not Sure [ ] (sketch shape)

      ↓ ↓ ↓



9. Do you normally wear earplugs with your helmet: NO YES
   a. If YES, what type of earplugs do you wear with your helmet?

      Foam [ ] Single flange [ ] Triple flange [ ] CEP [ ]
10. How many flight hours do you have using the HGU-56/P _____

Selection Criteria			If not qualified, reason for disqualification
Literacy (English)	GO	NO-GO	
Anatomical Features	GO	NO-GO	
Otoscopic Inspection	GO	NO-GO	
Pretest Audiogram	GO	NO-GO	
Training	GO	NO-GO	

_____

Principal Investigator's Signature & Date

Real-Ear Attenuation at Threshold Procedures – Method A

(1) Explain study and go over informed consent.

(2) Remove jewelry and glasses if necessary.

(3) Conduct otoscopic exam.

(4) Measure earcanal sizes and head dimensions.

Subject Measurements

Bitragion width: _____ mm Head height: _____ mm

HGU-56/P AIHS Size: _____

(5) Conduct screening audiogram.

Audiometric Screening

Frequency (Hz)		125	250	500	1000	2000	4000	8000
Pre-test	L	_____	_____	_____	_____	_____	_____	_____
(dB HL)	R	_____	_____	_____	_____	_____	_____	_____

_____

Audiologist/CAOHC Tech Signature & Date

(6) Conduct training with minimum of 5 open-ear sound-field audiograms.

(7) Ensure subject meets sele ction criteria.

---

(8) **Outside chamber**: Help the subject size and fit; may give verbal and physical assistance and use fitting noise.

(9) Subject removes HPD and enters chamber.

(10) **Inside chamber**:

i. Begin with open-ear test or have the subject fit HPD using fitting noise, but with NO ASSISTANCE from the experimenter.

ii. Before actual testing, the experimenter may visually check fit and require refitting for "best fit."

iii. Two-minute quiet period, before first threshold, either before or after the HPD is fitted.

iv. Measure open and occluded thresholds.

(11) **Testing Sequence**: (Device, Order, Test sequence)

Real-world fit: "Please put on your flight helmet the same way you normally do for flight operations."

HGU-56/P	_____	Occluded, Open	Open, Occluded
HGU-56/P & Balaclava	_____	Occluded, Open	Open, Occluded

Method A fit:

HGU-56/P (Method A)	3	Occluded, Open	Open, Occluded

Appendix C.

Analysis of variance summary table for the HGU-56/P versus HGU-56/P with balaclava comparison

Analysis of Variance Summary Table

Effect	*df* Effect	*MS* Effect	*df* Error	*MS* Error	*F*	*p*
Device	1	212.853	9	37.81385	5.6290	.041735
Frequency	6	2276.206	54	13.04916	174.4331	.000000
Device x Frequency	6	20.293	54	7.06356	2.8729	.016740

Appendix D.

Probabilities for Duncan multiple range post-hoc tests for the HGU-56/P versus HGU-56/P with balaclava comparison. Only the comparisons between means at the same center frequency test band are in bold. The statistically significant comparisons are underlined.

	HGU-56/P alone						
Hz	125	250	500	1000	2000	4000	8000
HGU-56/P w Balaclava Hz							
125	**.042160**	.036386	.000028	.000019	.000016	.000011	.000010
250	.058334	**.054174**	.000033	.000023	.000017	.000017	.000011
500	.071994	.077810	**.027905**	.000054	.000028	.000019	.000016
1000	.000033	.000054	.000120	**.714371**	.000054	.000028	.000019
2000	.000023	.000028	.000054	.265527	**.000113**	.000054	.000028
4000	.000017	.000019	.000028	.000054	.043162	**.375460**	.006818
8000	.000017	.000016	.000019	.000028	.000549	.358964	**.239959**

Appendix E

Analysis of variance summary table for the Informed-user versus Experimenter-supervised fit comparison

Analysis of Variance Summary Table

Effect	*df* Effect	*MS* Effect	*df* Error	*MS* Error	*F*	*p*
Method	1	11.644	9	16.49332	0.7060	.422542
Frequency	6	2294.961	54	25.08796	91.4766	.00000
Method x Frequency	6	6.695	54	5.26169	1.2723	.28553

Appendix F.

Probabilities for Duncan multiple range post-hoc tests for the Informed-user versus Experimenter-supervised fit comparison. Only the comparisons between means at the same center frequency test band are in bold. The statistically significant comparisons are underlined.

	Experimenter-supervised fit						
Hz	125	250	500	1000	2000	4000	8000
Informed-user fit Hz							
125	**0.62589**	0.18197	0.00003	0.00002	0.00002	0.00001	0.00001
250	0.71625	**0.21644**	0.00004	0.00003	0.00002	0.00002	0.00001
500	0.00015	0.00149	**0.64532**	0.00006	0.00003	0.00002	0.00002
1000	0.00003	0.00003	0.00006	**0.41113**	0.00011	0.00003	0.00002
2000	0.00002	0.00002	0.00003	0.00005	**0.53705**	0.00031	0.00003
4000	0.00002	0.00002	0.00003	0.00003	0.00028	**0.56118**	0.00007
8000	0.00002	0.00002	0.00002	0.00002	0.00003	0.06782	**0.01616**

Appendix G.

Maximum allowable exposure times for crewmembers in a CH-47D under different flight profiles with and without use of balaclava, based on DODI 6055.12.
(Arrows indicate time constraints that will limit some mission requirements.)

CH-47D Position	Condition	Allowable time hr/day HGU-56/P (MF)	w/ Balaclava	
Aft Cabin	90 knot	**2.6**	**1.6**	←
	Hover	5.9	**3.3**	←
	Ground Idle	14.9	8.0	
	APU	13.6	10.8	
Center Cabin	90 knot	**7.6**	**4.3**	←
	Hover	6.7	**4.0**	←
	Ground Idle	20.2	12.1	
	APU	24.0	24.0	
Forward Cabin	90 knot	24.0	24.0	
	Hover	24.0	18.0	
	Ground Idle	24.0	16.4	
	APU	24.0	24.0	
Right Cockpit Seat	90 knot	24.0	14.3	
	Hover	15.3	8.4	
	Ground Idle	16.0	9.0	
	APU	24.0	24.0	
Left Cockpit Seat	90 knot	24.0	18.8	
	Hover	18.0	10.3	
	Ground Idle	24.0	24.0	
	APU	24.0	24.0	

Appendix H.

Mean and standard deviations of the insertion loss of the HGU-56/P AIHS using the informed-user fit procedure.

Subject Number	Third-octave test band center frequency						
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
01	15.75	14.38	20.00	22.13	32.50	40.63	48.25
02	14.00	8.13	16.13	20.63	24.50	29.38	24.00
03	13.38	11.88	16.88	23.38	29.50	35.88	45.25
04	15.75	16.63	18.75	26.25	28.50	36.38	27.50
05	5.38	9.63	12.38	20.25	30.63	25.00	32.25
06	14.38	12.13	16.75	18.88	29.13	32.13	45.13
07	1.13	1.38	11.88	19.88	29.63	29.88	26.25
08	17.38	17.00	22.25	28.38	35.50	39.75	44.25
09	0.50	6.88	7.25	20.00	28.25	30.75	26.63
10	13.50	14.75	18.75	24.00	35.00	38.63	44.00
Mean	11.11	11.28	16.10	22.38	30.31	33.84	36.35
s	6.30	4.88	4.45	3.10	3.29	5.17	9.79
11	0.63	-0.88	8.63	19.75	23.88	26.75	20.88

Appendix I.

Mean and standard deviations of the insertion loss of the HGU-56/P AIHS worn with balaclava using the informed-user fit procedure.

Subject Number	Third-octave test band center frequency						
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
01	9.38	9.63	16.13	21.63	28.88	34.50	36.00
02	10.63	12.00	14.75	25.00	20.38	32.25	29.75
03	10.38	6.63	13.75	23.75	26.38	34.63	38.88
04	11.38	10.13	18.63	27.13	23.25	32.38	38.63
05	6.88	8.63	11.25	22.50	27.13	32.88	36.38
06	7.00	9.38	14.75	20.13	20.38	31.25	32.50
07	4.25	4.25	9.25	19.00	23.00	32.25	31.13
08	10.38	11.63	15.63	19.75	23.88	33.63	33.63
09	3.50	5.75	8.38	20.88	16.75	31.38	33.63
10	11.38	10.13	11.63	19.63	27.13	32.63	38.88
Mean	8.51	8.81	13.41	21.94	23.71	32.78	34.94
s	2.92	2.53	3.23	2.65	3.78	1.16	3.31
11	8.63	12.25	16.38	23.75	25.63	25.38	30.13

Appendix J.

Mean and standard deviations of the insertion loss of the HGU-56/P AIHS using the Experimenter-supervised fit procedure.

Subject Number	Third-octave test band center frequency						
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
01	19.00	18.75	24.13	21.75	32.75	40.50	50.00
02	9.88	13.13	16.13	22.38	22.63	35.25	27.13
03	11.75	9.50	16.63	26.88	29.25	37.38	46.38
04	17.13	17.00	22.13	27.13	31.50	42.63	49.25
05	10.38	13.13	13.63	18.38	25.63	23.25	30.38
06	16.00	14.13	16.50	16.50	30.88	35.25	47.75
07	1.38	1.38	7.63	16.13	28.25	28.00	24.38
08	16.63	16.75	19.88	23.75	33.25	37.75	44.00
09	0.75	5.13	5.38	16.88	28.25	28.88	23.25
10	13.63	17.50	23.75	25.50	34.38	35.50	46.50
Mean	11.65	12.64	16.58	21.53	29.68	34.44	38.90
s	6.33	5.70	6.37	4.31	3.64	5.99	11.13
11	19.88	13.88	14.25	24.13	25.88	41.25	43.25

Appendix K.

Occluded and unoccluded thresholds for each trial of the HGU-56/P AIHS using the informed-user fit procedure.

Condition	Trial	Subject Number	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Occluded	1	01	45.75	37.00	26.25	32.00	40.75	45.50	63.00
	1	02	50.00	35.25	27.50	37.50	43.75	49.75	51.50
	1	03	38.25	26.75	15.00	34.25	38.00	39.25	50.25
	1	04	45.50	33.75	25.00	40.50	44.50	40.00	44.25
	1	05	39.00	32.75	22.75	36.75	46.75	35.50	43.50
	1	06	45.25	34.50	25.00	35.50	44.50	49.00	59.50
	1	07	27.25	18.00	14.75	22.00	31.00	26.75	28.00
	1	08	45.00	40.00	30.75	43.25	51.00	49.00	63.25
	1	09	30.75	25.00	12.50	29.50	38.50	38.25	36.25
	1	10	53.00	40.25	28.75	41.50	50.50	51.50	65.00
Occluded	2	01	44.75	35.50	24.25	31.25	43.75	48.75	63.75
	2	02	47.50	40.25	29.50	43.75	45.75	49.50	53.25
	2	03	40.50	31.25	22.75	37.50	42.50	42.50	57.50
	2	04	44.00	36.50	26.25	40.00	47.50	47.25	44.00
	2	05	37.00	33.25	23.25	38.25	47.75	37.75	49.00
	2	06	43.75	32.50	22.00	32.00	45.75	46.50	60.50
	2	07	27.50	20.25	9.25	22.25	34.50	32.50	33.75
	2	08	46.75	39.25	29.75	42.75	51.75	47.00	62.50
	2	09	31.50	26.25	14.75	30.25	36.75	39.50	38.00
	2	10	54.25	41.25	32.50	42.50	53.25	50.50	68.75
Unoccluded	1	01	27.50	21.00	6.50	9.50	9.75	6.75	14.00
	1	02	35.50	30.00	12.25	19.50	18.25	20.00	28.75
	1	03	25.25	15.00	1.25	11.75	11.00	5.50	7.50
	1	04	29.25	18.75	7.25	14.00	18.25	7.50	16.75
	1	05	31.75	21.75	10.75	17.00	17.50	12.75	15.00
	1	06	30.75	21.00	7.00	14.00	15.50	13.50	15.00
	1	07	25.00	17.75	2.75	2.00	4.25	0.75	2.75
	1	08	27.50	23.50	9.25	12.25	14.75	9.00	18.25
	1	09	31.50	20.75	6.00	8.75	9.25	8.50	10.00
	1	10	42.25	26.00	12.75	16.25	16.00	11.75	23.00
Unoccluded	2	01	31.50	22.75	4.00	9.50	9.75	6.25	16.25
	2	02	34.00	29.25	12.50	20.50	22.25	20.50	28.00
	2	03	26.75	19.25	2.75	13.25	10.50	4.50	9.75
	2	04	28.75	18.25	6.50	14.00	16.75	7.00	16.50
	2	05	33.50	25.00	10.50	17.50	15.75	10.50	13.00
	2	06	29.50	21.75	6.50	15.75	16.50	17.75	14.75
	2	07	27.50	17.75	-2.50	2.50	2.00	-1.25	6.50
	2	08	29.50	21.75	6.75	17.00	17.00	7.50	19.00
	2	09	29.75	16.75	6.75	11.00	9.50	7.75	11.00
	2	10	38.00	26.00	11.00	19.75	17.75	13.00	22.75

Appendix L

Occluded and unoccluded thresholds for each trial of the HGU-56/P AIHS worn with balaclava using the informed-user fit procedure.

Condition	Trial	Subject Number	125.00	250.00	500.00	1000.00	2000.00	4000.00	8000.00
Occluded	1	01	42.00	34.00	25.25	34.00	38.50	41.50	51.00
	1	02	46.00	39.50	28.00	40.50	36.50	46.50	57.00
	1	03	36.25	25.25	17.00	37.50	38.25	40.75	46.25
	1	04	41.00	29.25	25.50	38.75	41.25	40.25	56.00
	1	05	38.00	33.00	24.25	40.00	43.50	44.00	52.25
	1	06	37.75	28.50	19.00	34.25	31.75	43.25	45.75
	1	07	30.75	20.75	10.25	20.50	26.50	28.75	34.25
	1	08	39.00	33.75	23.25	38.00	41.75	43.25	50.75
	1	09	36.50	27.00	14.50	31.75	28.50	39.25	44.75
	1	10	49.00	40.50	29.75	40.75	46.00	48.50	64.00
Occluded	2	01	43.25	34.75	25.50	32.75	38.75	44.25	50.50
	2	02	43.75	37.75	26.00	41.25	36.50	46.75	57.00
	2	03	37.50	26.25	16.25	37.00	38.50	42.25	48.75
	2	04	38.50	28.50	23.25	40.25	39.00	38.00	56.75
	2	05	42.00	32.25	22.25	39.75	44.25	44.25	51.50
	2	06	35.25	29.50	20.50	37.00	38.25	43.25	49.00
	2	07	32.25	22.75	15.50	20.50	25.75	32.50	37.75
	2	08	43.25	37.00	26.50	39.25	46.50	44.50	54.00
	2	09	36.25	28.25	17.75	31.75	24.00	38.00	44.50
	2	10	50.75	37.75	25.75	41.75	46.25	48.00	64.50
Unoccluded	1	01	33.25	25.75	9.75	12.25	9.50	8.25	13.50
	1	02	34.00	24.50	11.50	15.25	15.50	14.50	26.25
	1	03	26.75	19.50	1.50	14.75	11.00	7.50	7.75
	1	04	28.25	18.75	6.00	13.25	17.50	6.50	16.75
	1	05	33.00	23.75	11.25	16.25	15.75	10.25	15.00
	1	06	29.50	21.00	5.50	15.25	14.50	12.25	15.50
	1	07	26.25	17.00	1.75	0.50	3.75	-4.50	3.50
	1	08	30.75	23.50	8.50	19.50	19.25	10.25	18.75
	1	09	32.50	20.25	5.25	8.75	8.25	6.75	11.50
	1	10	39.00	29.75	17.25	20.00	19.50	15.25	23.25
Unoccluded	2	01	33.25	23.75	8.75	11.25	10.00	8.50	16.00
	2	02	34.50	28.75	13.00	16.50	16.75	14.25	28.25
	2	03	26.25	18.75	4.25	12.25	13.00	6.25	9.50
	2	04	28.50	18.75	5.50	11.50	16.25	7.00	18.75
	2	05	33.25	24.25	12.75	18.50	17.75	12.25	16.00
	2	06	29.50	18.25	4.50	15.75	14.75	11.75	14.25
	2	07	28.25	18.00	5.50	2.50	2.50	1.25	6.25
	2	08	30.75	24.00	10.00	18.25	21.25	10.25	18.75
	2	09	33.25	23.50	10.25	13.00	10.75	7.75	10.50
	2	10	38.00	28.25	15.00	23.25	18.50	16.00	27.50

Appendix M.

Occluded and unoccluded thresholds for each trial of the HGU-56/P AIHS using the Experimenter-supervised fit procedure.

Condition	Trial	Subject Number	125.00	250.00	500.00	1000.00	2000.00	4000.00	8000.00
Occluded	1	01	47.50	41.25	28.75	34.75	45.50	49.25	65.75
	1	02	49.00	42.25	30.75	40.25	44.00	54.50	55.75
	1	03	40.25	29.75	23.50	37.75	41.75	44.00	54.75
	1	04	46.25	35.50	28.25	38.75	48.00	50.50	65.75
	1	05	41.75	38.00	27.00	39.25	45.00	35.25	47.25
	1	06	46.00	32.75	22.25	31.25	42.25	48.50	60.75
	1	07	30.75	18.00	15.50	23.00	33.50	30.00	31.00
	1	08	46.75	42.75	35.25	43.50	54.50	50.00	65.25
	1	09	34.00	27.25	14.75	27.50	39.00	37.75	34.25
	1	10	58.00	48.00	33.75	43.00	51.50	50.50	69.75
Occluded	2	01	48.25	39.50	28.25	31.75	42.50	47.00	63.25
	2	02	50.00	42.25	32.25	40.25	43.25	56.00	56.25
	2	03	41.00	30.75	22.00	40.50	42.50	44.25	57.25
	2	04	48.00	37.75	29.75	40.50	50.75	49.25	68.50
	2	05	46.75	38.50	27.25	41.00	50.00	40.00	53.25
	2	06	45.00	34.50	23.25	32.25	46.00	48.75	62.25
	2	07	29.25	21.75	12.50	25.25	33.50	32.75	33.50
	2	08	46.25	42.00	31.25	42.25	52.25	49.25	63.50
	2	09	34.50	28.25	14.25	29.50	38.75	38.25	36.00
	2	10	52.50	44.25	34.75	43.75	50.75	50.75	72.25
Unoccluded	1	01	29.25	21.25	4.25	11.00	12.25	7.75	14.75
	1	02	39.25	29.50	16.00	19.75	20.75	19.00	28.75
	1	03	29.50	21.00	7.25	12.00	12.00	7.25	9.75
	1	04	29.25	19.00	7.00	12.75	18.25	5.75	17.75
	1	05	33.25	25.50	14.75	20.25	21.75	12.50	19.75
	1	06	28.00	20.50	8.50	16.50	14.00	14.00	14.00
	1	07	29.25	21.00	6.75	8.25	5.50	5.50	8.25
	1	08	33.25	27.25	14.75	18.75	18.50	11.25	19.25
	1	09	33.50	22.75	10.25	10.50	10.75	9.50	13.25
	1	10	41.50	27.25	9.75	15.25	17.50	17.75	25.00
Unoccluded	2	01	28.50	22.00	4.50	12.00	10.25	7.50	14.25
	2	02	40.00	28.75	14.75	16.00	21.25	21.00	29.00
	2	03	28.25	20.50	5.00	12.50	13.75	6.25	9.50
	2	04	30.75	20.25	6.75	12.25	17.50	8.75	18.00
	2	05	34.50	24.75	12.25	23.25	22.00	16.25	20.00
	2	06	31.00	18.50	4.00	14.00	12.50	12.75	13.50
	2	07	28.00	16.00	6.00	7.75	5.00	1.25	7.50
	2	08	26.50	24.00	12.00	19.50	21.75	12.50	21.50
	2	09	33.50	22.50	8.00	12.75	10.50	8.75	10.50
	2	10	41.75	30.00	11.25	20.50	16.00	12.50	24.00